FOCUS OF THE HOT DRY ROCK PROGRAM AFTER RESTRUCTURING

Dave Duchane
Earth and Environmental Sciences Division
Los Alamos National Laboratory
(505) 667-9893

ABSTRACT

Since the early 1970's, the technology for extracting useful amounts of geothermal energy from hot dry rock (HDR) has developed from the conceptual stage to a demonstration of the technical feasibility of routine production of high-grade geothermal energy from HDR. On the basis of extremely promising flow-test results at the Fenton Hill, NM HDR test facility, the USDOE issued a solicitation in late 1994 seeking industrial partners to construct and operate a plant to produce and market energy derived from an HDR resource. Although bids were received and a DOE-appointed technical review committee recommended the project go forward, the solicitation was withdrawn in October 1995. At the same time, the DOE directed the Fenton Hill facility be completely decommissioned and announced a restructuring of the US HDR program.

In December 1995 a geothermal industry panel commissioned by the Geothermal Division of the DOE reviewed the HDR program. Although the industry group made a number of general recommendations, it deferred specific program actions to future deliberations. The DOE is now considering convening two groups to address the future of HDR. A panel working under the auspices of the National Academy of Sciences (NAS) would conduct an in-depth review of HDR and outline a visionary path to the eventual implementation of HDR technology. A second group, representing geothermal stakeholders, would provide advice and guidance to the DOE on the implementation of specific HDR projects to assure that HDR technology, while moving toward the vision developed by the NAS panel, at the same time contributed to achieving the near-term goals of the conventional geothermal industry.

A multi-faceted HDR program will be required if both the expressed national goal of worldwide leadership in the development, application, and export of sustainable, environmentally attractive, and economically competitive energy systems, and the more expedient goals of the geothermal industry are to be achieved. It is suggested that a restructured HDR program should have components that involve industry-coupled projects to apply HDR-developed technologies to the improvement of hydrothermal productivity, a search for niche opportunities for immediate HDR deployment, and an increased level of participation in foreign HDR projects.

INTRODUCTION

In 1970, researchers from the Los Alamos National Laboratory filed for a US Patent on a process employing hydraulic fracturing to extract heat from a dry geothermal reservoir (Potter et al 1974) The concepts outlined in that patent application formed the basis for the United States HDR Program formally initiated in 1974, and for subsequent work on the extraction of energy from HDR in England, Japan, the European Community, and a number of other countries around the world.

Since its inception, HDR work in this country has been sponsored by the USDOE and its predecessor agencies. Domestic HDR research and development work has been conducted primarily under the direction of the Los Alamos National Laboratory, with most field experiments carried out at the HDR test site at Fenton Hill in the Jemez Mountains of northern New Mexico. Under an International Energy Agreement, Japan and Germany participated in the development of the Fenton Hill HDR facility from 1980 to 1986, contributing both financing and technical personnel to the HDR project.

BACKGROUND

After a few tentative heat flow and hydraulic fracturing experiments, the development of the world's first HDR system began at Fenton Hill in 1974. A small reservoir was created by hydraulic fracturing in granitic rock at a depth of about 9,850 ft and a temperature of 365°F. This reservoir, together with the two wellbores penetrating it, formed the Phase I HDR system. The Phase I system was evaluated in a series of flow experiments between 1978-1980 (Dash et al 1981). These tests demonstrated the scientific feasibility of extracting heat from engineered geothermal reservoirs.

In 1980, work was begun on a much larger, deeper, and hotter, Phase II HDR reservoir. It was not until 1986, that the Phase II system was completed and initially flow tested (Dash 1989). Since that time, the Phase II reservoir has been subjected to extensive evaluation under both static and flow conditions. It is undoubtedly the most-characterized and best-understood, fully-engineered geothermal reservoir in the world. The Phase II reservoir is centered at a depth of about 11,400 ft in rock at a temperature of 420-460°F. Seismic, hydraulic, tracer, and geometric measurements indicate that the Phase II reservoir has a flow-connected volume of 200-800 million cubic feet (on the order of 50 to 200 times the volume of the Phase I reservoir).

Between 1987 and 1991, a permanent surface plant was constructed at Fenton Hill and mated to the Phase II wellbores (Ponden 1991). The complete Phase II system today consists of a highly automated, closed loop in which the same water can be continuously recirculated. Thermal energy is absorbed from the hot rock during each pass through the reservoir and then rejected via an air-cooled heat exchanger at the surface. A high pressure injection pump provides the sole motive force for the operation.

A series of flow tests of the Phase II HDR system was conducted between 1992 and 1995 (Brown 1996, Brown 1993). Under the steady-state conditions maintained during most of the testing, the injection pressure was typically held at about 3,960 psi, the highest level that could be maintained without causing an increase in the reservoir volume. This pressure was high enough so that the injected water could be returned to the surface at backpressures as high 2,200 psi without large reductions in the rate of production. A few of the tests involved operation under cyclic conditions during which the injection and production conditions were intentionally varied to demonstrate that the output of an HDR reservoir could rapidly adjusted to meet changing demands for power.

Both the steady-state and cyclic production testing programs were highly successful. Approximately 100 billion BTU's of thermal energy was extracted from the Phase II reservoir during a total of about 11 months of steady-state circulation over a span of 4 years. Although small changes in the temperature distribution were noted in the open-hole production interval at the bottom of the production wellbore, no decline was observed in the temperature of the fluid produced at the surface. Cyclic testing demonstrated that energy production could be increased by about 60% from a baseline level within a period of only 2-3 minutes, held at that elevated level for 4 hours, and then be rapidly reduced back to the baseline output for the remainder of a 24-hour repetitive production cycle. Obviously, many other cyclic production schedules might be employed in the operation of an HDR facility to obtain the maximum economic return, but limited project resources did not permit further evaluation of this energy production strategy.

The flow testing series provided solid evidence that water loss need not be a serious problem in the operation of HDR reservoirs. Water consumption declined directly as a function of the time the system was held at operating pressure, reaching a level of only 7% of the injected volume on a trend line that indicated an eventual decline to 2-3% or even less. Dissolved solids remained at low levels and the circulating fluid picked up essentially no suspended solids. Because the HDR plant was fully-automated, all the flow testing was conducted with a minimum of manpower. The site was typically run unmanned at night.

With encouraging flow test results in hand, the DOE issued a solicitation in December 1994 seeking an industrial partner to develop a facility to produce and market energy from an HDR resource. Bids were received from several organizations. In late June 1995, a technical review committee appointed by the DOE selected a winning bidder and recommended that the project go forward. Several months later, in October 1995, the DOE canceled the solicitation, stating that it would continue to pursue research and development on HDR but not commercialization at this time. Concurrently, a directive was issued to decommission the Fenton Hill site. Restructuring of the HDR Program is now in progress.

A RESTRUCTURED HDR PROGRAM

The announcement that the HDR Program would be restructured was first made by Karl Rabago, then DOE Deputy Assistant Secretary for Utility Technologies, in a speech at the opening of the Geothermal Resources Council meeting in Reno, Nevada on October 8, 1995. While that speech made the intent to restructure the HDR Program clear, it was vague on the goals and direction of the restructuring. A subsequent memo from the DOE Geothermal Division to the Department's Albuquerque Operations Office offered a little more insight into the future of the HDR program, stating:

> "Rather than pursue a commercialization goal, the Department will refocus the Geothermal Hot Dry Rock Program to work with industry and other interested parties to resolve the key technical issues. Los Alamos National Laboratory (LANL) is expected to play a continuing role in technology development."

The above statement makes two major assertions: 1) The HDR program will be refocused to work more closely with industry and other interested parties and, 2) Los Alamos National Laboratory will continue to play a role in HDR development. The "key technical issues" referred to in the memo have not yet been explicitly identified. Apparently, one of the first tasks under the restructured HDR program will be for the DOE Geothermal Division, industry, and other interested parties to delineate these key technical issues and formulate a plan to address them.

Initial Steps in Restructuring the HDR Program: In December 1995, the Geothermal Energy Association (GEA), at the direction of the DOE Geothermal Division, convened a geothermal industry panel to make recommendations on the future course of HDR research and development. The panel first engaged experts from the US geothermal industry, the national laboratories, other government agencies and foreign HDR programs in discussions of the status of HDR technology. It then met in executive session to develop a set of "industry" recommendations on the future course of HDR in the US These recommendations were immediately presented in preliminary form to Allan Hoffman, DOE Acting Deputy Assistant Secretary for the Office of Utility Technologies.

In a report that so far has appeared only in "draft" form, but the essence of which was printed in a recent Geothermal Resources Council Bulletin, that group affirmed the importance of HDR to the future of the geothermal industry, suggested that HDR technology should be integrated into the conventional geothermal industry, and proposed that the acronym "HDR" be replaced with a new term that would encompass all geothermal resources requiring artificial measures beyond current technology to achieve commercial heat extraction. They did not, however, offer any suggestions as to what the new term should be. The group also made the following specific recommendations:

- Unify management of all geothermal R&D programs and include HDR elements within the unified program.
- Convene a panel to formulate short- and long term geothermal R&D goals, including the long-term commercialization of HDR.
- Establish a peer-review committee to evaluate the current status of the US HDR Program, publish its findings, and implement technology transfer to move HDR technology into the geothermal mainstream.
- Mothball the Fenton Hill site.
- Coordinate US geothermal R&D efforts with HDR programs in other countries.

Impending Restructuring Activities: The GEA panel offered some broad directions but few specifics in regard to the future course of HDR research and development. While the panel endorsed a much closer tie of HDR work to the goals of the hydrothermal industry, it gave no indications of exactly how to accomplish this. With this background, the DOE Geothermal Division now appears to be considering a dual approach to restructuring the HDR Program that will move toward the vision of the United States as a "worldwide leader in the development, application, and export of sustainable, environmentally attractive, and economically competitive energy systems" as expressed in the DOE's strategic plan of April 1994, while at the same time addressing the more immediate concerns of the conventional geothermal industry. Two complementary groups are being considered to help set the course of future HDR work. One panel, under the auspices of the National Academy of Sciences, would review the status of HDR technology in depth and provide a visionary outline of a path to eventual HDR implementation. The second group, more geothermal industry oriented, would address HDR in the context of its relationship to the conventional geothermal industry.

A National Academy of Sciences Review of HDR: A review of HDR by a National Academy of Sciences (NAS) panel may the single most important factor in establishing a reinvigorated HDR Program. An NAS review would certainly be widely recognized as authoritative, independent, and unbiased. Hopefully, the result of an NAS review of HDR would be a realistic assessment of the current state of HDR technology and a visionary plan to make HDR and the full range of geothermal resources, a key component of the clean energy supply the world will need in the 21st century.

An NAS review could bring national stature to geothermal energy by focusing the attention of DOE upper management, other government agencies, wide segments of the energy and environmental communities, and the public at large, on HDR and geothermal energy in general. In this way, the review could help provide wider appreciation of the current contributions of geothermal energy to the nation's clean energy goals. Furthermore, recognition of HDR as a ubiquitous resource of national importance with a proven potential for deployment, would foster the increased public support for geothermal energy that will be essential if federal financial assistance to geothermal development is to be maintained in these times of shrinking national budgets.

A Geothermal Industry Review Board for HDR: The function of the geothermal industry review board will be to work closely with the DOE to define the specifics of the HDR Program. The board will assure that HDR is integrated into the mainstream of the geothermal research program, develop or endorse projects that apply HDR technology to the improvement of hydrothermal productivity, and advise the DOE on the direction of HDR work, especially in the near-term. Hopefully the membership of the board will be drawn from the full spectrum of geothermal stakeholding organizations. Ideally, the geothermal industry HDR review board will be an ongoing entity that will first provide input to the NAS panel and then work with the DOE Geothermal Division to implement the NAS vision for HDR in a manner compatible with the aims of the geothermal industry. While the industry board may be charged with developing and prioritizing HDR projects, the DOE, acting as the agent of the US taxpayer, must make the final programmatic decisions in the face of budgetary limitations and broad departmental renewable energy goals.

OPTIONS FOR A RESTRUCTURED HDR PROGRAM

The most important restructuring challenge is to formulate an HDR program that more closely allies the goals of HDR with the needs of the private geothermal industry, while at the same time holding to the central promise of HDR technology. That promise - transforming geothermal energy from its current perceived status as a localized resource with limited potential to that of a widely recognized world-class energy resource that will be one of the important contributors to providing the 21st century world with clean energy available virtually everywhere - must be met if the geothermal industry is to prosper and grow in the long run.

In order to reconcile the national HDR goals with the immediate interests of the conventional geothermal industry, a multi-faceted HDR effort will be required that: 1) applies HDR technology to the solution of near-term hydrothermal problems, 2) capitalizes on special opportunities to develop HDR technology in projects complimentary to hydrothermal technology, and 3) promotes international cooperation both to maximize the effectiveness of HDR research and development work underway in a number of countries around the world, and to assure US leadership in HDR development and marketing in countries that are just beginning to explore the potential of HDR as an indigenous energy resource. Each of these potential facets of a restructured HDR Program is discussed in more detail below.

Industry-Coupled HDR Technology Applications: Cooperative Projects which apply HDR technology and expertise to the solution of hydrothermal problems and increase the productivity of hydrothermal or quasi-hydrothermal (hot wet rock) reservoirs have the potential to provide almost immediate benefits to the geothermal industry. During more than 20 years of work on HDR, unique capabilities in drilling, hydraulic fracturing, fracture location and characterization, reservoir engineering, logging tool design and application, fluid injection, and reservoir modeling have been developed. In some instances, especially in regard to drilling and logging-tool development, significant technology transfer has occurred via the service companies that have at times been involved in the HDR project. However, in other areas such as reservoir engineering, fracture mapping and characterization, reservoir modeling, and fluid injection, there has as yet been little effective technology transfer to the hydrothermal industry

One aspect of a restructured HDR program might therefore be the development of industry-coupled projects to apply HDR reservoir mapping and fracture location techniques to the identification and location of fractures in hydrothermal fields. The information thereby generated could reduce the incidence of drilling "dry holes" and thereby markedly lessen field development costs. A second joint project might entail applying HDR expertise in injection and stimulation to make existing dry holes at hydrothermal sites productive and/or to develop engineered reinjection plans that would ensure that reinjected fluid (or supplementary injected fluid such as that to be delivered via the Geysers/Clearlake pipeline) is most effectively utilized to enhance energy production. Yet a third application of HDR technology might involve the application of HDR reservoir models to hydrothermal situations, particularly those concerned with reinjection or pressure maintenance and fluid production problems, in order to better understand how to limit declines in reservoir productivity.

The project areas described above are presented from an HDR perspective. Undoubtedly, industry engineers and scientists could modify them to most effectively meet the current hydrothermal research and development needs. Obviously, any of these projects are worth pursuing only if they have the solid support of one or more industrial organizations and can potentially contribute to improving the technical competence and competitive status of the US geothermal industry.

HDR Niche Development Projects: Cooperative projects which bring HDR technology to bear on hydrothermal problems will result in immediate useful applications of HDR technology, but this approach will not move geothermal energy toward the national stature needed to assure continued support from the federal government and the taxpaying public. In order to accomplish the latter goal, we must continue to pursue the development of HDR processes that can be implemented in those non-hydrothermal regions that underlay the vast majority of the US.

With the closure of Fenton Hill, a highly visible effort to advance heat mining technology in its widest sense - as a means of tapping the ubiquitous HDR resource - becomes more important than ever. This effort must include a continued search for a new site that can provide opportunities for field work in an HDR environment.

The knowledge base accumulated during work at Fenton Hill can be applied to develop a new HDR site that may have practical as well as research and development applications. In view of the depressed price for electric power generation in the US, any such domestic HDR site must fit into either an especially attractive electricity niche (due to advantageous resource characteristics or local economic factors that lead to high electricity prices) or be located where these is an opportunity for a direct use application of the HDR energy. Direct use opportunities should be carefully evaluated and developed, as appropriate, in cooperation with private industry as well as state and local government entities that may have an interest in energy or economic development. Given the current bleak outlook for the electricity market in those parts of the US where hydrothermal resources are found, niche applications of HDR may at present represent one of the few opportunities for additional domestic geothermal development. Finding a niche for HDR in today's highly competitive energy marketplace is a challenging task but, for all of the above reasons, it must be pursued if HDR and, indeed, the geothermal industry itself, is to have any chance of being a significant factor in the US energy picture of the future.

Increased International HDR Activities: HDR research and development has had an international flavor almost since its inception. The high point of international cooperation was reached during the period from 1980 to 1986 when Japan and Germany participated both financially and technically in the work to develop the large HDR reservoir at Fenton Hill. The international contacts made during those years have led to continued international cooperation in the form of periodic personnel exchanges and international meetings. For example, the 3rd International HDR Forum to be held in May 1996, at Santa Fe, NM, will bring together dozens of HDR workers from both Europe, Japan, and elsewhere to exchange information with their US colleagues and explore ways to work more closely together.

At present, US leadership in HDR technology is recognized worldwide, but with the closure of the only domestic HDR field site, that leadership role is likely to be assumed by Japan or the European Community. The US is thus likely to move from the position of serving as a primary source of new technical information and ideas for the international HDR community to one of heavy reliance on foreign HDR work to supplement a downsized HDR development program. In this light, increased international cooperation becomes an imperative for the domestic HDR program.

Efforts to increase international cooperation in geothermal energy via a new International Energy Agreement (IEA) have been underway for some time. The Japanese have taken the lead in the area of HDR and are proposing their New Energy and Industrial Development Organization (NEDO) be the operating agent for all HDR work conducted under the auspices of the IEA. Four project areas have been suggested for joint work. These include HDR economics, applications of hydrothermal technologies to HDR development, coordination of data acquisition and processing developments, and joint development of reservoir assessment technologies.

Although the US is in the process of passing the mantle of leadership in HDR to nations that are more aggressively pursuing the technology, a window of opportunity remains to work with nations that now have fledgling HDR efforts. At present, engineers and scientists from these countries typically turn to US HDR experts for background information and initial guidance. As these nations develop field programs, the drilling, wellbore services, and other industry-based work may accrue to US companies if a relationship with the US HDR research community has been established. In fact, providing technical support today for these blossoming HDR projects may be the only means of assuring US participation in the international HDR energy market that could develop by the early years of the next century.

SUMMARY

Work at the Fenton Hill test site in northern New Mexico has taken HDR from the purely conceptual stage through a demonstration of the technical viability of exploiting this ubiquitous geothermal resource. The USDOE is now in the process of closing Fenton Hill and restructuring the HDR program to more closely align it with the immediate goals of the US geothermal industry. The industry, through the GEA, recently affirmed the importance of HDR. At the same time, the GEA made number of general restructuring recommendations, but deferred the formulation of specific actions to future deliberations. The DOE is now considering a dual approach to restructuring the HDR program, under which a National Academy of Sciences panel would review HDR technology and develop a visionary path to HDR implementation, while a geothermal industry board would provide more immediate guidance to the DOE in regard to the implementation of specific HDR projects.

It is suggested that a restructured HDR program should have three essential elements: 1) Industry coupled projects that apply HDR technology to the solution of near-term hydrothermal problems, 2) projects that maintain the validity of geothermal energy as a national resource by moving toward development of the water-deficient geothermal resources found throughout the nation, and 3) increased participation in international HDR activities. Taken together, these elements must meet the domestic geothermal industry needs of today while assuring that the US will have a significant role in the HDR world of tomorrow.

REFERENCES

1 Potter, R.M., E.S. Robinson, and M.C. Smith, Method of Extracting Heat from Dry Geothermal Reservoirs, U.S. Patent #3,786,858, 1974.

2. Dash, Z.V., H.D. Murphy, and G.M. Cremer, Eds., "Hot Dry Rock Geothermal Reservoir Testing: 1978 to 1980," Los Alamos National Laboratory Report LA-9080-SR, 1981.

3. Dash, Z.V., ed., ICFT: "An Initial Closed-Loop Flow Test of the Fenton Hill Phase II HDR Reservoir," Los Alamos National Laboratory Report LA-11498-HDR 1989.

4 Ponden, R.F., "The Design and Construction of a Hot Dry Rock Pilot Plant," Proceedings of the US Department of Energy Geothermal Program Review IX,, 1991, p 149-151.

5. Brown, D.W., "Recent Flow Testing of the HDR Reservoir at Fenton Hill, New

Mexico," *Geothermal Resources Council Bulletin*, **22** (8), Sept., 1993, pp 208-214.

6. Brown, D.W., "Experimental Verification of the Load-Following Potential of a Hot Dry Rock Geothermal Reservoir," Proceedings of the Twenty-First Workshop on Geothermal Reservoir Engineering, Stanford Univ., Stanford, CA, in press, 1996.